It is notable that current regulations mandate automatic sprinkler protection for electrical cable trays, tunnels, shafts, chases, cable spreading rooms, and penetrations. National Fire Protection Association (NFPA) Standard 803, "Fire Protection for Nuclear Power Plants," [10] contains the current complement of recommended practices for fire protection in nuclear power plants, including guides for fire prevention programs and considerations of fire risk and prevention for new construction. Items missing from this standard include guidelines for fire prevention and long-term fire protection during and after power plant decommissioning. Tables 9.2 and 10-1.2 of this standard respectively detail general criteria for fire detection and suppression installations in all facilities of a power plant.

Prior to the Browns Ferry fire, the use of water on electrical fires was not considered a safe practice. Following the Browns Ferry fire in 1975[a,b] (see USNRC NUREG-0050, "Recommendations Related to the Browns Ferry Fire," February 1976), in USNRC NUREG-0050, February 1976,[11] Factory Mutual (now FM Global) and other organizations performed studies to test the use of water in electrical spaces (see EPRI NP-1881[12] and EPRI NP- 2660).[13] In addition, Sandia National Laboratories (SNL) performed tests on cable tray protection schemes (see USNRC NUREG/CR 3656,[14] NUREG/CR-2377,[15] and NUREG/CR-2607,[16] as well as SNL reports SAND 83-2664, SAND-81-7160,[17] and, SAND 82-0431).[18] These studies by Factory Mutual and other organizations showed that fighting fires in grouped cables could be accomplished efficiently with the use of water (these tests were done on unenergized electrical cables, however, the conclusions on the use of water as an efficient extinguishing agent were confirmed). Following the Browns Ferry fire and the tests performed by Factory Mutual, SNL, and others, the inhibition against using water to put out fires in all spaces with electrical equipment seemed to subside, and fire protection engineers made more deliberate assessments of the type of electrical occupancy when considering use of water as a fire suppressant.[19,20]

On July 2, 1980, another incident involving HEPA filters occurred at Rocky Flats. In this event, a high-temperature excursion occurred in the final filter plenum of a waste disposal incinerator. Water deluge was initiated in the plenum, and the incident was secured. Investigators determined that a bypass valve of a heat exchanger failed open, allowing metal fines from corrosion processes and nitric acid collection by the first filter bank. It was further found that nitric acid exothermically reacts with the urethane seals of the HEPA filters, which could then ignite the metal fines. Water deluge reduced plenum temperature, and the fire department "mopped-up."

No flames were ever observed during the incident. The first three stages of the four-stage filter array were severely damaged by combined excess heat and water exposure. The remaining stage was intact, allowing no contaminants to escape the confinement plenum of the incinerator.[21] Moreover, improvements in detection system technology and in fire-resistant materials were significant in that decade. It is probably safe to say that the two production line fires could not be repeated in the systems operating in the current decade. The question posed by the 1980 incinerator fire is: "What effect does water exposure have on HEPA filter stability and endurance in a fire environment? It is known that any water damage to the filters resulted from a water spray system because fire department activities did not include water application.

In the spring and summer of 2000, the DOE complex experienced wildland fires at the Los Alamos National Laboratory (LANL), Idaho National Engineering and Environmental Laboratories (INEEL), and Richland, Washington, sites. These fires, particularly the one at LANL, impacted the ventilation systems at the site by clogging intake filters and causing evacuation of all but essential personnel on those sites.

10.3 CODES AND STANDARDS

Decisions regarding the extent and nature of fire safety features for confinement ventilation systems are predicated to a significant degree on the regulatory environment governing the facility. That environment can be characterized as being "external," for those facilities regulated by the U.S. Nuclear Regulatory Commission (USNRC) or "internal" for those facilities owned by Government entities like the DOE. The applicability of any fire safety criteria to a particular design will be dependent upon the nature of the license application (for a USNRC-regulated facility), the contract (for a federal facility) and the governing regulations (such as 10 CFR Part 70).[22] Proceeding with an individual design should not progress until the technical (safety) basis is clearly established.

Designers and operators should be cognizant of the significant differences in the requirements and guidelines for fire protection related to these differing regulatory environments. For example, there is a significant difference between USNRC and DOE directives concerning the provision of automatic fire suppression to ensure the viability of ventilation systems. DOE has more conservative criteria reflecting the unique radiological hazards characteristic of the weapons complex.

Fire protection requirements and guidelines for confinement ventilation systems are delineated in a number of USNRC and DOE source documents. These include USNRC Regulatory Guides, Standard Review Plans, Branch Technical Positions and supplementary staff position papers. DOE directives include Order 420.1, "Facility Safety," its Implementation Guide for Fire Protection,[23] and DOE-STD-1066,[8] "Fire Protection Design Criteria."

While the expectation exists that these criteria be implemented, a "variance" approval process exists within both the USNRC and the DOE. The process in general includes a documented description of the condition, the justification for literal nonconformance, and approval by the fire protection "authority having jurisdiction (AHJ)."

Despite the differences in scope between USNRC and DOE fire safety directives relating to confinement ventilation systems, the following are significant common requirements.

- <u>Compliance with applicable industry standards, such as those promulgated by the NFPA</u>. Prominent among these is the 800 Series of Standards on fire protection for nuclear facilities and NFPA Standard 90A, "Installation of Air Conditioning and Ventilation Systems."[24] Note that cost-effective alternative means of compliance is permitted under established "equivalency" provisions.
- Development of a comprehensive fire hazards analysis (FHA). The FHA is required to consider under all operating modes the potential adverse impact of the spread of products of combustion through the ventilation system.
- Implementation of combustible materials and ignition source controls to minimize the potential for fire.
- Use of generally noncombustible structural elements and "listed" fire protection system components that are subjected to a quality assurance (QA)/quality control (QC) program.
- Provision of fire protection defense-in-depth. This means that multiple fire safety features are available in the event that one is rendered inoperable.
- Reliance on both active (e.g. fire detectors and sprinklers) and passive (e.g. fire barriers) fire safety features.
- A comprehensive inspection, testing and maintenance program for installed fire safety features.
- A trained staff capable of responding in a timely and effective manner to fires and related emergencies.

Specific fire safety features that are stipulated in this body of criteria are considered acceptable <u>minimums</u>. There may be circumstances that will warrant the provision of additional protective measures to compensate for elevated fire hazards or unusual risks. Such hazards and risks may be revealed in conjunction with the formulation of the fire hazards analysis, the application of fire modeling techniques, and on the basis of the results of engineering surveys.

An issue that has resulted in a degree of regulatory inconsistency concerns the application of industry standards retroactively. DOE has established the concept of "codes of record," that are defined as the codes and standards that were in force at the time a facility design commenced. Newly promulgated industry standards can only be imposed upon an existing facility when the AHJ determines that there is a compelling reason on the basis of health and safety to the public and site workers.

Questions regarding the applicability of individual fire safety directives to a particular confinement ventilation design as well as requests for interpretation of the provisions of industry standards to such designs should be directed to the cognizant USNRC or DOE fire protection authority having jurisdiction.

10.4 ENCLOSURE FIRE MODELING IN FIRE HAZARDS ANALYSIS

DOE has developed a useful framework for analyzing the fire hazard in a facility. This framework considers all of the aspects of fire and its impact on people, continuity of operation, the environment, and the public. The occurrence and spread of fire is a complex process that cuts across many design and operational disciplines which makes its control over the lifetime of a facility problematical in some respects.

The FHA for a confinement ventilation system should contain a conservative assessment of the following issues and their relation to fire.

- Description of construction
- Description of critical process equipment
- Description of fire hazards, including a design basis fire and its effects on the confinement ventilation system, and the limits of the ability of the confinement ventilation system to withstand fires more severe than the design basis fire
- Protection of essential safety class systems
- Life safety considerations
- Critical process equipment
- Identification of high-value property
- Identification of the damage potential: Maximum Credible Fire Loss (MCFL) and Maximum Possible Fire Loss (MPFL)
- Analysis of Fire Department/Brigade response and its adequacy
- Recovery potential
- Potential for a toxic, biological, and/or radiation incident due to a fire
- Analysis of Emergency Planning and its ability to mitigate a fire in a confinement ventilation system
- Security and Safeguards considerations related to fire protection
- Impacts of natural hazards (earthquake, flood, wind) on fire safety
- Exposure fire potential, particularly concerning the potential for breaching of the confinement ventilation system due to a fire external to the system

The FHA considers everything to do with the design and operation of the facility. The essential tools for analysis are predictive models that can be applied to define the ranges of hazards from design basis events (DBEs). An FHA can be applied during the design phase of new facilities and/or in conjunction with changes or modifications of existing operations. Fire models for FHAs range from simple algorithms that predict thermodynamic changes in enclosures to complex programs that can account for heat, mass transfer, and smoke production in multiple enclosures. Many mathematical models have been installed in computer codes and are available on the Internet bulletin boards of various government agencies. These codes can predict development and spread of fire and smoke conditions through multiple rooms, and can account for changes in the structure and composition of enclosures. Application of these models requires considerable understanding of their use and limitations, statements of which are usually included in the instructional text that is published with the code. Information about these codes is found in Section 10, Chapters 6 through 14 of the 17th edition of the NFPA Handbook.[25] Reduction of complex models to simple terms supported by empirical data can often be useful in making predictions of uncomplicated systems.

As shown, the temperature of the hot upper layer formed by fire in the LLNL fire test cell is plotted and compared to a temperature correlation based on the mass flow rate of air, the heat release rate of the fire, and the thermal properties of the test cell surfaces. While this model does not have an